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# DESIGN, DEVELOPMENT, AND TESTING OF A LIGHTWEIGHT OPTICAL SENSOR COVER SYSTEM

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## ABSTRACT

This paper discusses aspects of the design, development and testing of the sensor cover on the Clementine (DSPSE) spacecraft. Particular attention is given to defining the typically ambiguous issue of cleanliness (i.e. how clean is clean?). To characterize performance with respect to these requirements, a simple and effective method for testing prototype seals was developed. This testing was useful for comparing various types of seals as well as for providing information about achievable cleanliness levels. The results were invaluable input for defining a realistic final cleanliness requirement that satisfied everyone from mechanisms to sensor engineers.

Balancing torque margins (reliability) versus cost and/or weight of the system can be significantly influenced by choice of seal type. Several seal types are discussed in terms of both cleanliness and ease of implementation. These design issues influence actuator selection and structural integrity of the door.

The cover system designed and fabricated as described above was thoroughly tested both on a component level and on the Clementine system level. Testing included characterization, vibration, pyro-shock, life, and thermal/vacuum. The extensive testing identified problems early enough that they could be resolved prior to integration and launch.

## INTRODUCTION

As more and more sensors are being flown, sensor covers are becoming a standard mechanisms subsystem on most satellites today. The two primary functions of a sensor cover are to protect the optics from debris and from exposure to excessive radiation. These cover functions lead to some level of sealing requirement and, often, a repeatable use requirement.

The Clementine spacecraft carries a cluster of five optical instruments to be used for imaging and ranging. The instruments were arranged in a relatively tight cluster to utilize a single optical bench and allow use of a single cover.

## WHAT IS CLEAN?

A primary driver for design of a protective cover is defining what types of contaminants must be kept away from the optics. Considering the various environments (and what is known about them) encountered from integration through flight operation, establishing a realistic definition can be difficult. Over-specifying can lead to an over-complex design and threaten the reliability of the cover system. Under-specifying can lead to inadequate protection and allow contamination that could degrade instrument performance.

Ground handling and launch environments are relatively well understood. The primary contaminants to control are air born particles stirred up and/or carried by air currents. Covers also protect from inadvertent contact by hands or tools during integration and handling. Conditions during flight are more difficult to evaluate. During instrument operation the cover must be open, of course, and the optics are exposed to any contamination that may be present. Design engineers must determine whether protection is necessary during periods when increased contamination is expected (delta-V burns, maneuvering with thrusters, passage through zones of "space dust", etc.). Determining whether to add the complexity of a cover versus no cover at all is a difficult problem which must be solved considering the instrument and flight requirements specific to the given mission.

The requirements for the optics on Clementine were evaluated based on mission requirements and events. It was determined that protection for the optics was required during a solid rocket burn during flight as well as during ground operations and launch. It was also desirable to be able to close the cover if higher levels of contamination were encountered or if maneuvers caused extended exposure to solar radiation. The primary concern was to avoid particulate contamination on the optics surfaces. Sealing requirements for the cover were established such that the optics would be protected against particles larger than 0.1 mm diameter while the cover was closed.

## SEAL DEVELOPMENT TESTS

The requirements for particulate protection established that a hermetic seal was not required. In considering the design of the cover and seal two basic approaches were compared. The choice of seal would have a significant influence on the drive system design. The first approach was to use an "energized" seal such as an O-ring or a wipe type contact seal (similar to weather stripping on a door). The second

was to use a non-energized seal such as a labyrinth seal. During the initial design stages it was thought that an energized seal would probably provide better sealing, but would also require much higher torques to open and then to re-close and re-seal. The non-energized seal would be preferred from a drive mechanism point of view, but might not provide adequate sealing. Because of potential problems with sticking an O-ring/elastomeric seal was not considered.

In order to obtain additional information on seal effectiveness and related torque requirements a quick and dirty seal test was conceived. Two cover mock-ups were fabricated. One was made with a wipe seal made from Kapton strip and the other with a labyrinth seal. The covers were made from a clear plastic so that the interior space could be inspected without opening the cover. Each cover was then placed in a chamber and subjected to a dust-filled environment. Figure 1 shows the chamber with a cover/seal mock-up.

Several substances were investigated as particle sources for the desired particle distribution. Of the easily obtained sources, flour provided the best distribution with particles ranging from approximately 0.05mm to 0.5mm diameter. The flour was introduced into the chamber using a high speed air stream. During the tests the covers were held closed under several different conditions to simulate environments expected during flight. The air currents swirled the flour forcefully throughout the chamber, coating all surfaces with dust. The mock-up cover was then removed, the exterior was carefully cleaned, and the protected area was inspected for particles that may have intruded past the seal.

The test results indicated that the labyrinth seal tested provided better protection than the Kapton wipe seal. This approach was approved and the labyrinth seal was incorporated into the design. A cross section of the cover system showing the drive components and a portion of the seal area is shown in Figure 2. The seal geometry is shown in Figure 3. Figure 4 is a photograph of the competed cover system.

## SUMMARY

The success of the labyrinth seal allowed the use of a very lightweight cover and drive system. The non-energized seal did not require a heavy cover structure to establish adequate sealing. The system could also operate with lower torques, allowing al lightweight, reliable drive system. The total mass of the drive system, cover, and mating seal was 1.38 kg.

The flight cover system was delivered to the Naval Research Laboratory in August, 1993. Acceptance testing, including system characterization, vibration, pyro-shock, life and thermal/vacuum, was completed. Several anomalies were identified and resolved by mid-November, 1993. The spacecraft was successfully launched on January 25, 1994.

LESSONS LEARNED

1. Defining realistic cleanliness requirements for an instrument requires a balance between the actual needs of the optics, the anticipated environmental conditions, and the practicality of designing and using an adequate cover system.

2. Very simple, easily interpreted tests can provide information critical for comparing different, but apparently equivalent, design approaches.

3. The "flour test" is a rigorous development test invaluable for characterizing a seal system.

4. Extensive acceptance testing of the flight system can identify anomalies that can then be quickly resolved prior to integration and launch

TABLES AND FIGURES

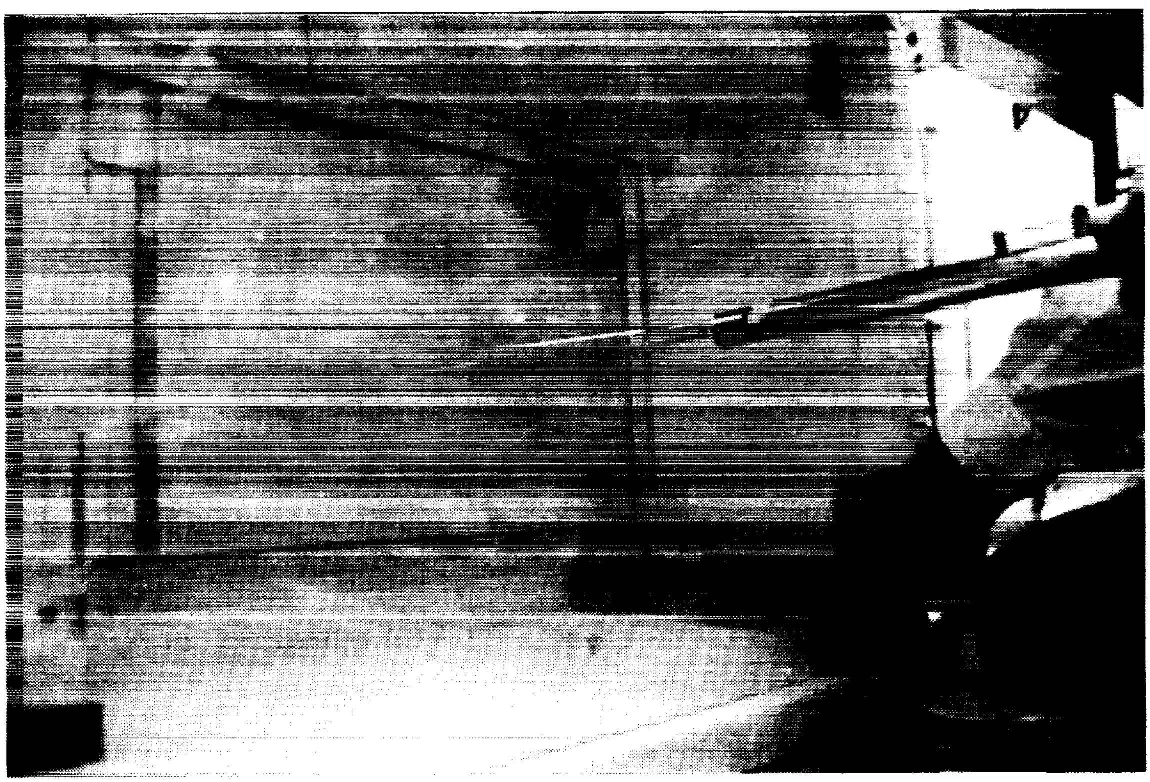

Figure 1. Seal mock-up and test chamber during flour test.

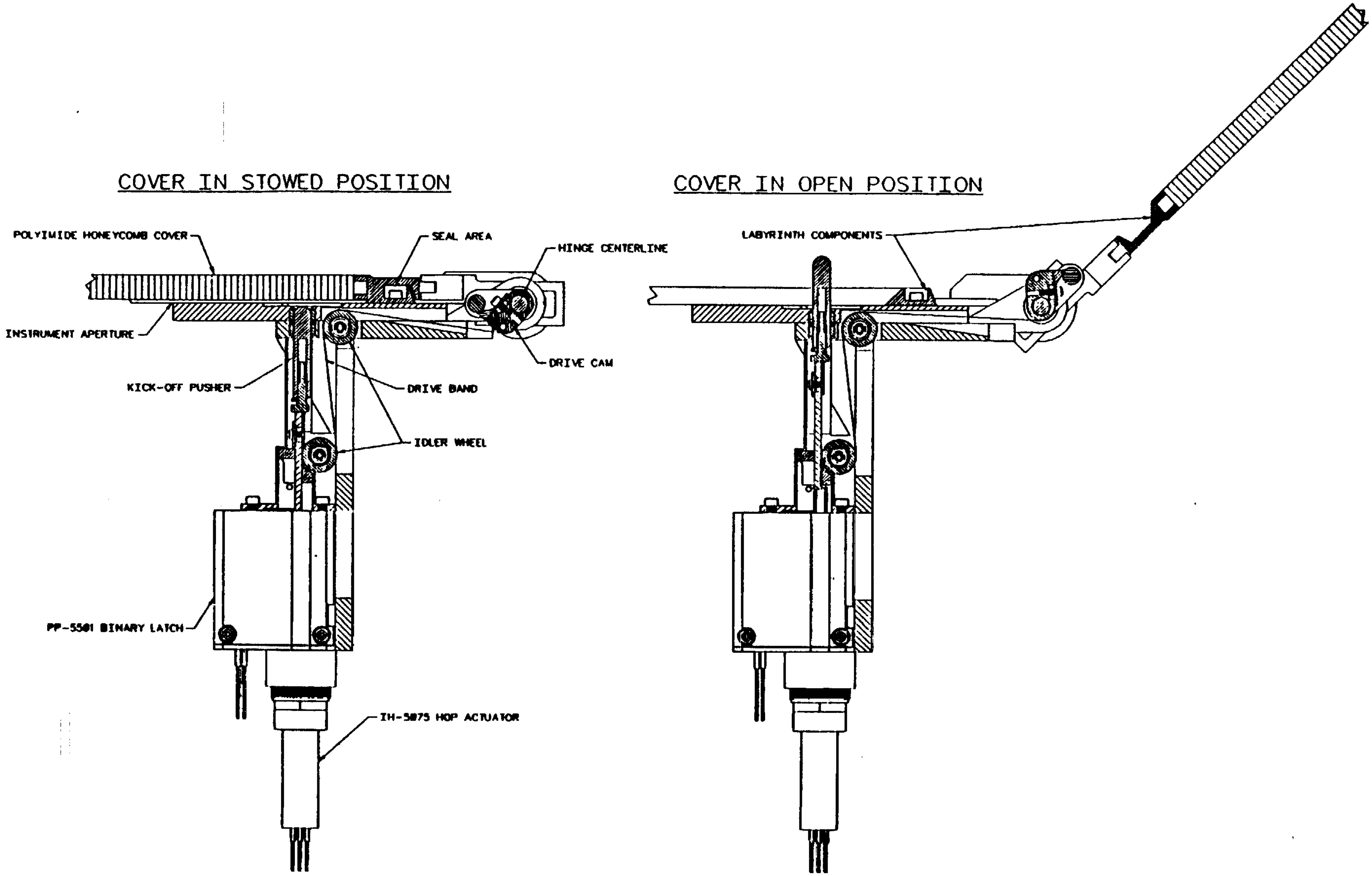


Figure 2. Partial cross section of cover, seal, and drive mechanism for Clementine sensor cover system.

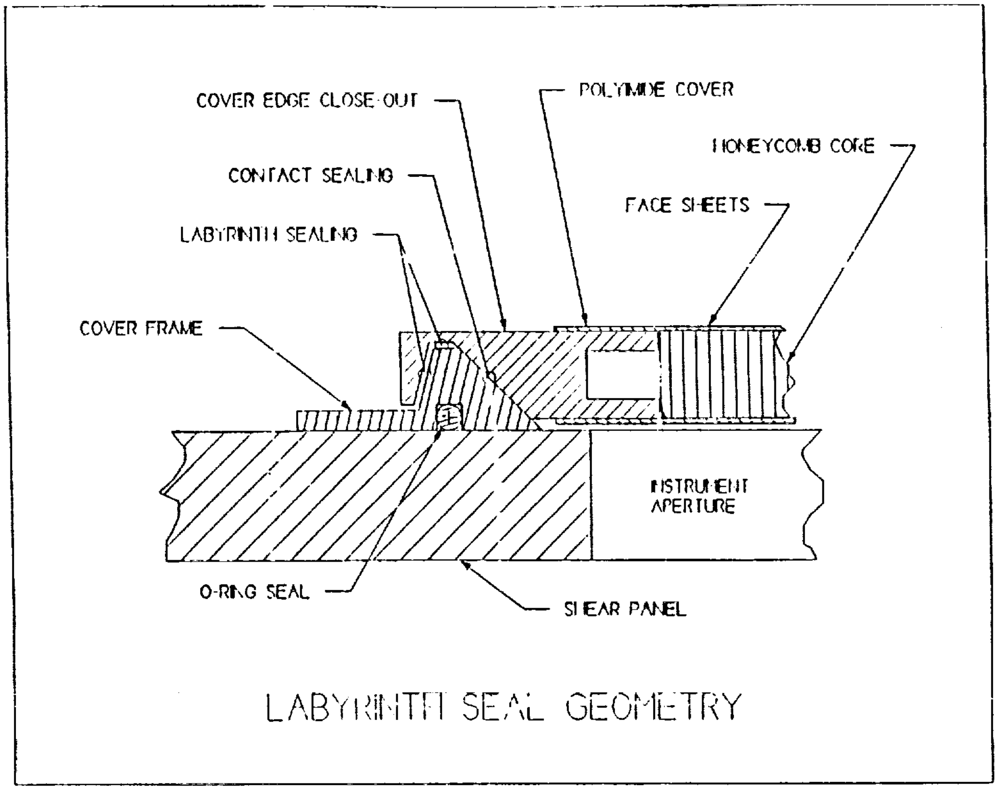


Figure 3. Labyrinth seal geometry.

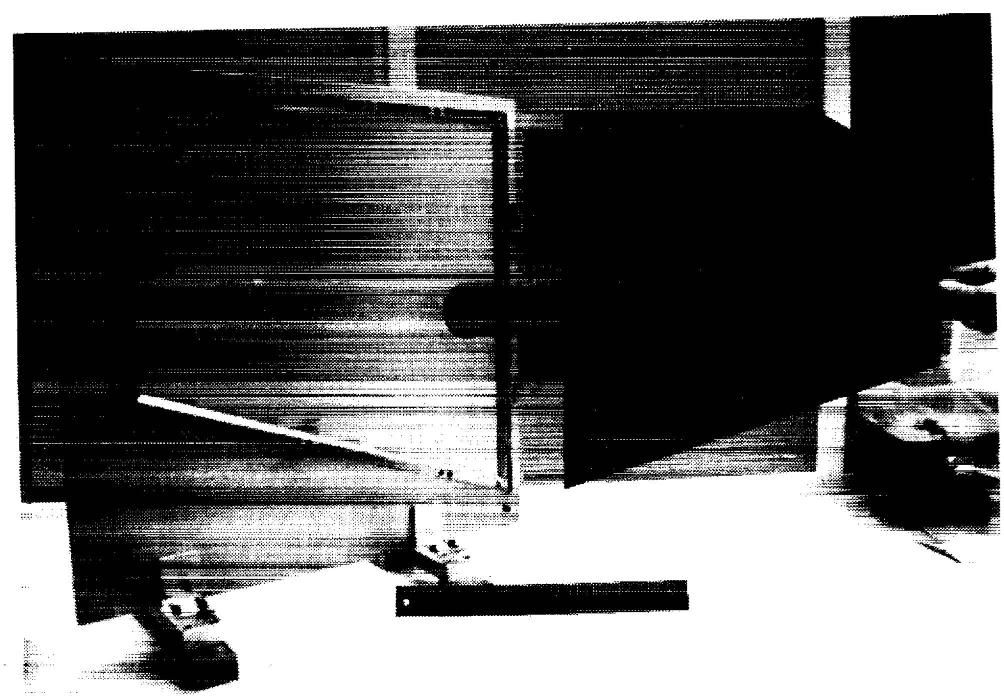

Figure 4. Compete cover system mounted to test plate.